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(56) Documents Cited
GB 2271779 A GB 2266564 A US 5470666 A

(58) Field of Search
UK CL (Edition S) C7A
INT CL[7] C22C
Online: PAJ, WPI

(54) Abstract Title
Aluminium alloy bearing material

(57) A bearing alloy comprising (in % by weight): tin 5-10 %, copper 0.7-1.3 %, nickel 0.7-1.3 %, silicon 1.5-3.5 %, vanadium 0.1-0.3 % and manganese 0.1-0.3, with the balance being aluminium and unavoidable impurities. Also, a plain bearing comprising a backing material 12 (e.g. steel or bronze) onto which a layer of the bearing alloy 14 is bonded. There may be an interlayer 16 of aluminium or aluminium alloy between the backing material 12 and the bearing alloy 14. The outer surface of the bearing alloy 14 may be provided with an overlay coating layer.

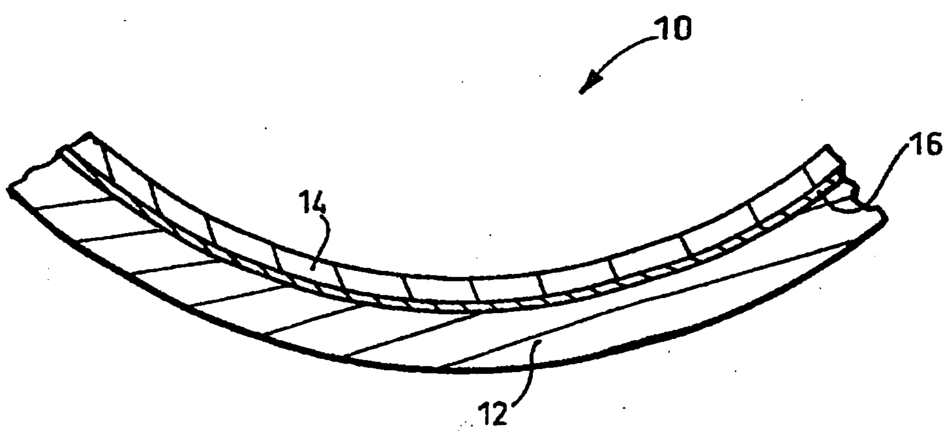

Fig.1.

GB 2 358 872 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

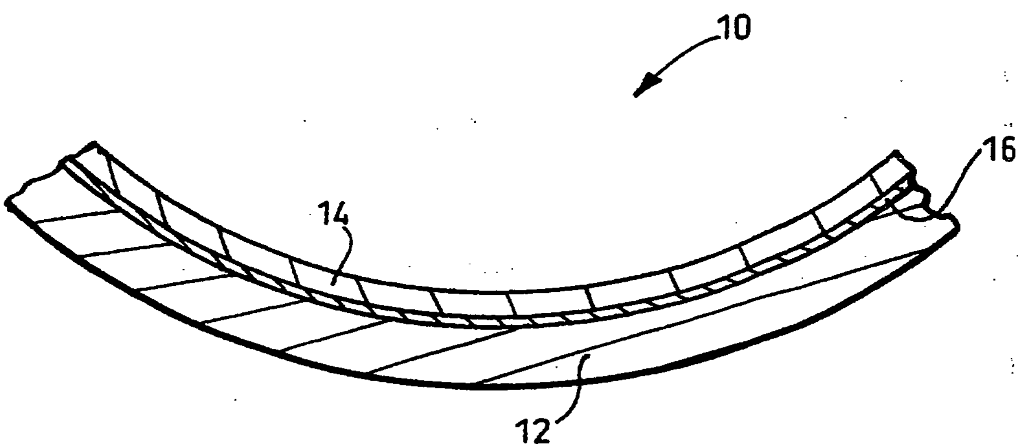

Fig.1.

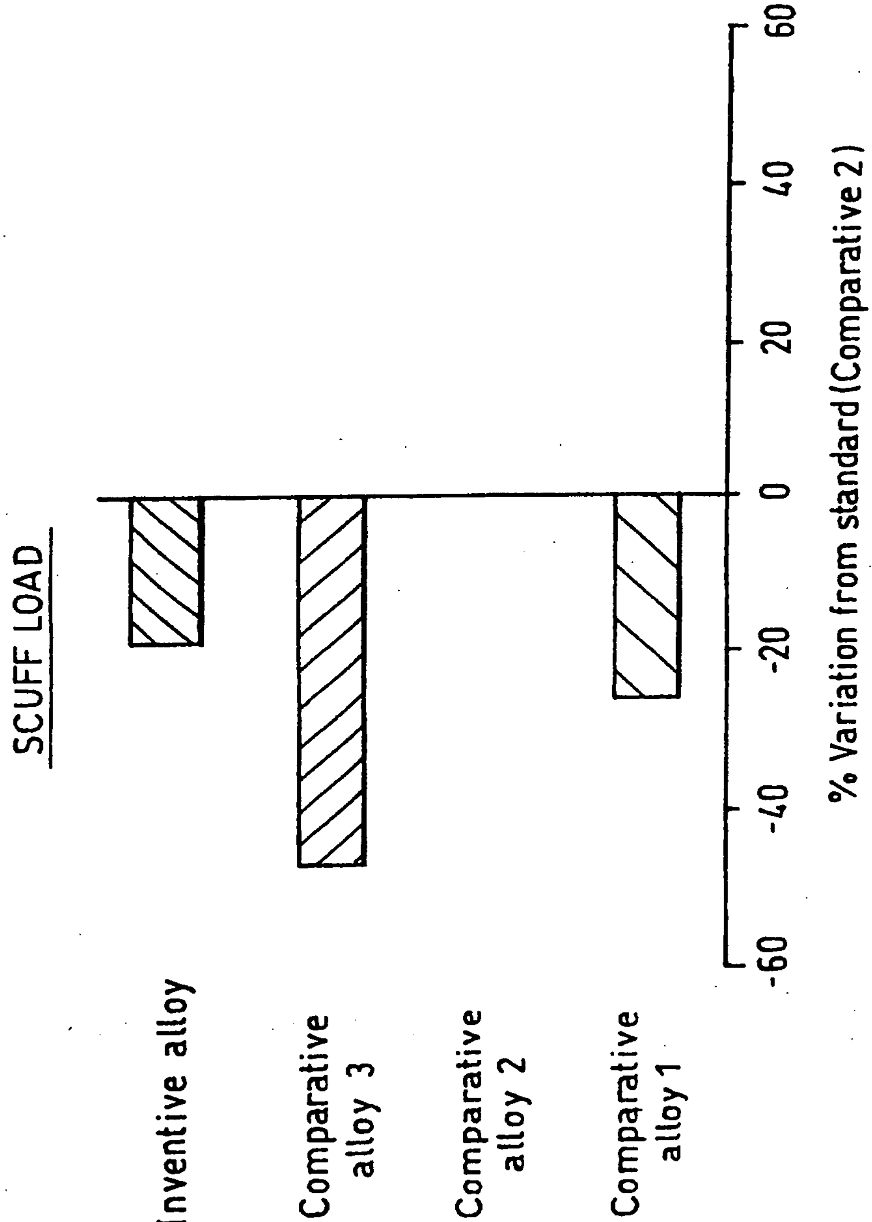
SCUFF LOAD
Inventive alloy
Comparative alloy 3
Comparative alloy 2
Comparative alloy 1
-60
-40
-20
0
20
40
60
% Variation from standard (Comparative 2)

Fig.2.

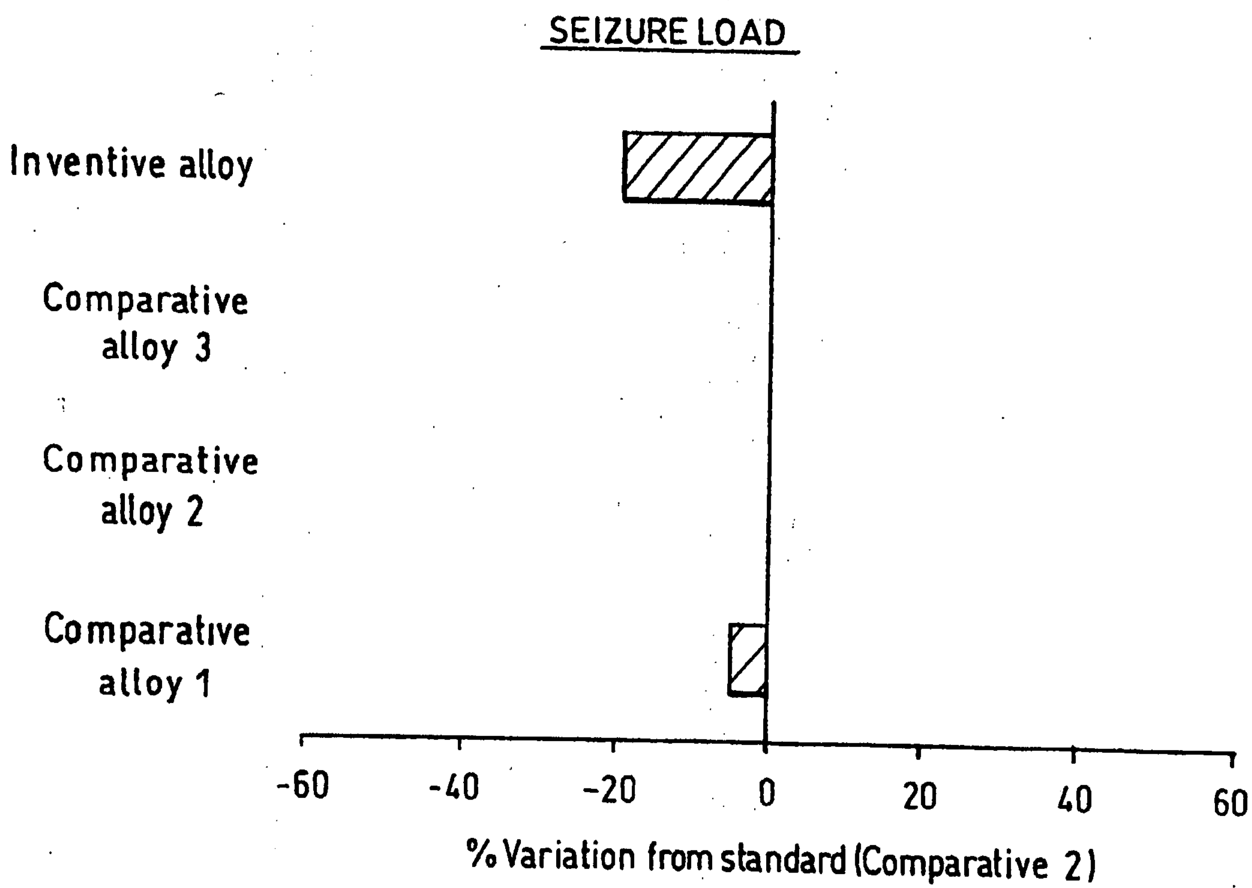
SEIZURE LOAD
Inventive alloy
Comparative alloy 3
Comparative alloy 2
Comparative alloy 1
-60
-40
-20
0
20
40
60
% Variation from standard (Comparative 2)

Fig.3.

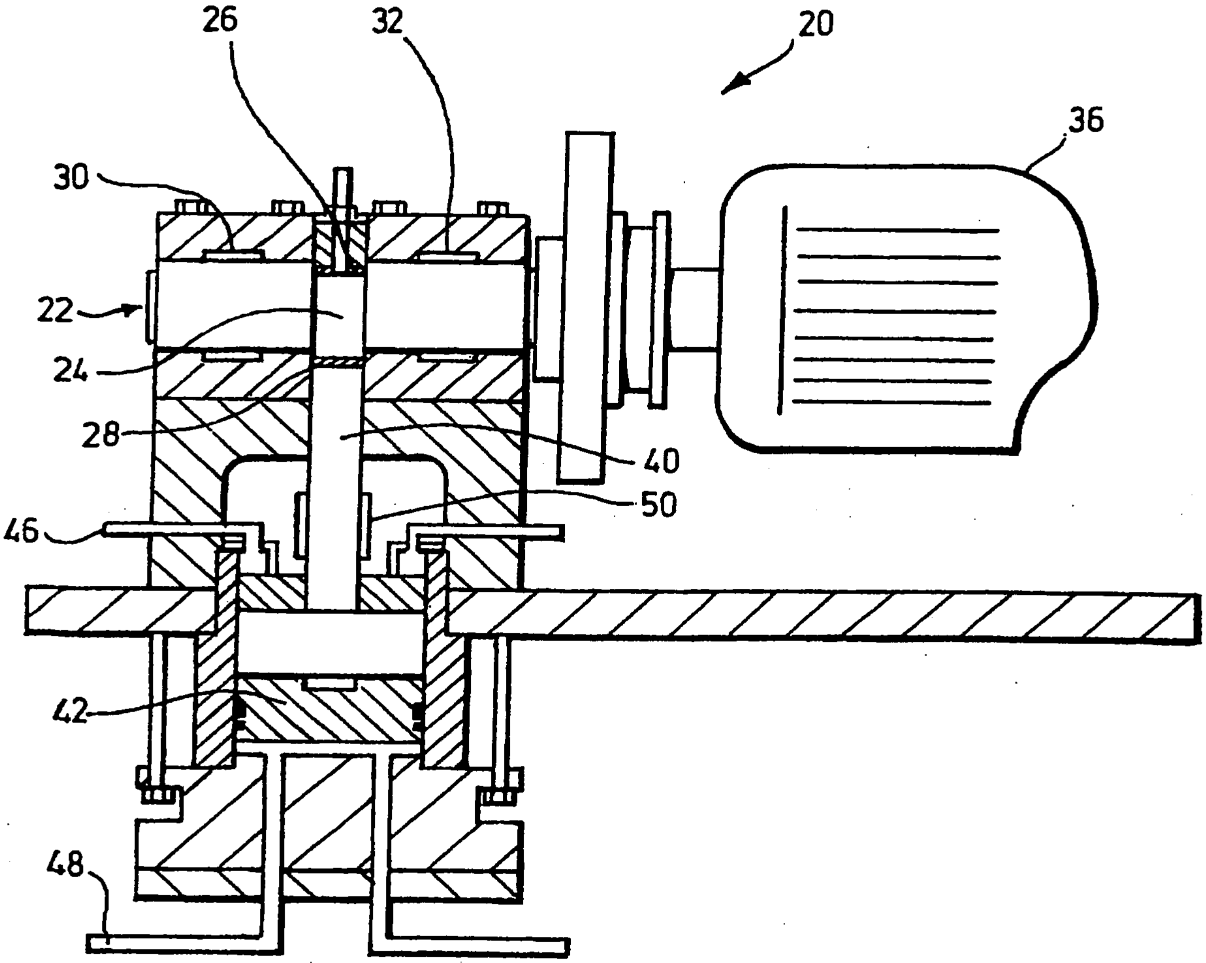

Fig.4A.

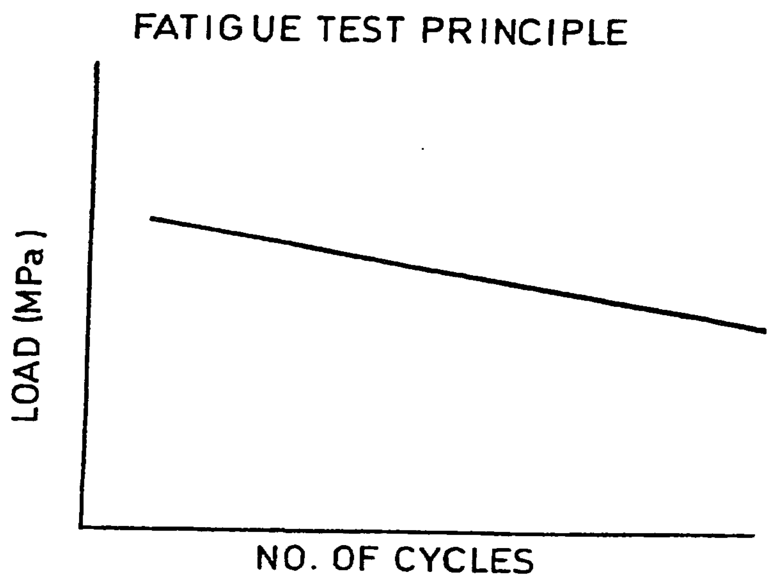
FATIGUE TEST PRINCIPLE
LOAD (MPa)
NO. OF CYCLES

Fig.4B.

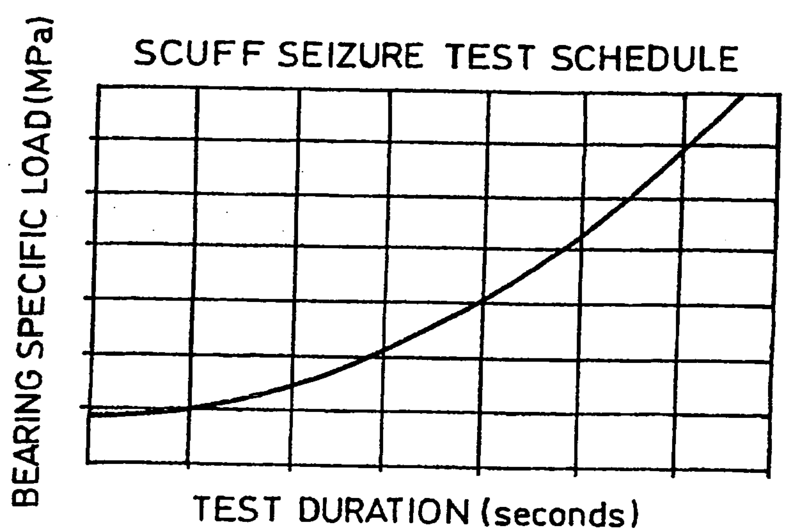
SCUFF SEIZURE TEST SCHEDULE
BEARING SPECIFIC LOAD (MPa)
TEST DURATION (seconds)

Fig.4C.

BEARING MATERIALS

The present invention relates to bearing materials comprising aluminium alloys bonded to a strong backing material.

Highly rated internal combustion engines have conventionally used crankshaft bearings comprising either a copper based alloy or an aluminium based bearing alloy bonded in some manner to a strong backing or substrate material such as steel for example. The actual working surface of the bearing alloy, i.e. that surface which faces the engine crankshaft journal surface has also been provided with a so-called overlay coating which is a thin coating of a relatively softer metal alloy such as lead-tin, lead-tin-copper or lead-indium for example. The purpose of the overlay coating is to provide conformability and dirt embeddability properties to the bearing. Conformability is that property of a bearing which allows it to accommodate slight mechanical misalignments between the bearing and shaft surfaces and is a measure of the ability of the overlay alloy to distribute the applied load. Dirt embeddability is that property which allows debris particles in the lubricating oil to be embedded in the soft overlay alloy without causing damage such as scoring of the shaft. Whilst the technical advantages of overlay coated bearings are not disputed they have the significant disadvantage of being expensive to make due to the overlay generally being deposited by electroplating which is a relatively very labour intensive process.

Manufacturers of motor vehicles are more frequently asking for bearings which do not have overlay coatings as they are cheaper to buy. However, some engines whilst not

possessing a particularly high specific output, due to their design, impose high loads on the crankshaft bearings or possess particularly thin oil films between the bearing and shaft journal and are consequently prone to "scuffing" of the bearing surface. Scuffing is where metal to metal contact between the crankshaft journal surface and the bearing surface occurs, i.e. the oil film at the point of contact is ruptured allowing metal to metal contact. Scuffing relates to momentary metal to metal contact without actual seizure and consequent failure of the bearing. However, whilst overlay coated bearings are especially scuff resistant, most of the conventional copper and aluminium based alloys are relatively poor in terms of scuff resistance. The ability to withstand scuffing is a measure of the conformability of the alloy. In contrast to scuffing, seizure is related to lack of compatibility of the alloy.

One known material comprising aluminium-6wt% tin-1wt% copper-1wt% nickel has good scuff resistance but has a relatively low fatigue strength and toughness in the non-overlay plated condition which renders it unsuitable for more modern highly rated engines. The low fatigue strength and toughness is a reflection of the low ductility of this alloy.

To cope with the stresses imposed by modern engines, an alloy having significantly improved mechanical properties, viz. tensile strength (15%); hardness (15%); and fatigue strength (16%) than one of the strongest known aluminium bearing alloys comprising: aluminium-12wt% tin-4wt% silicon- 1wt% copper which is in a solution heat treated form, is required. Whilst the strength of this alloy could be raised by increasing the copper content it is difficult and expensive to make by

the usual production methods of casting billets and rolling to size and roll-pressure bonding to steel owing to the small size reductions which are possible at each rolling pass before annealing heat treatment is required.

GB-A-2271779 describes an aluminium/tin/silicon bearing alloy which may further comprise at least one of the elements Mn, Mg, V, Ni, Cr, Zr, and/or B at between 0.1 and 3.0 weight% per element. In addition to these elements, the alloy further contains 0.2 to 5.0 weight% Cu, 0.1 to 3.0 weight% Pb, 0.1 to 3.0 weight% Sb and 0.01 to 1.0 weight% Ti as additional alloying elements. It is explained that if the content of the optional elements Mn, Mg, V, Ni, Cr, Zr and B rises above 3.0 weight% the conformability of of the bearing may deteriorate and workability of the bearing alloy can be degraded.

GB-A-2266564 is also concerned with aluminium-based bearing alloys similar to GB'779 described above. In this case the alloy also preferably includes At least one or two further elements of from 0.2 to 5.0 weight% Cu, from 0.1 to 3.0 weight% Pb, from 0.1 to 3.0 weight% Sb, Mn, Mg, V and Ni and 0.01 to 1.0 weight% Ti, the total amount of Mn, Mg, V and Ni being in the range from 0.01 to 3.0 weight%.

However, alloys made according to the teachings of the above two documents are virtually unprocessable by the normal production methods of casting and rolling followed by roll-pressure bonding due to lack of ductility and brittleness of the alloys. This is the case when the alloying element contents are a small fraction of those quoted.

It is an object of the present invention to provide an aluminium alloy having greater strength and scuff resistance than known alloys whilst retaining ease of manufacture.

According to a first aspect of the present invention, there is provided a bearing alloy composition comprising in weight%: tin 5-10; copper 0.7-1.3; nickel 0.7-1.3; silicon 1.5-3.5; vanadium 0.1-0.3; manganese 0.1-0.3; balance aluminium apart from unavoidable impurities.

Preferably, the tin content lies in the range from 5.5-7 weight%.

Bearing testing has surprisingly shown that when the silicon content falls below 1.5wt% then the incidences of seizure increases. When the silicon content exceeds 3.5% then the silicon network tends to be coarser and the incidence of cracking during alloy processing, by rolling for example, increases significantly necessitating additional in process heat treatments and smaller rolling reductions per pass thus, increasing the cost of production. Preferably, the silicon content is maintained within the range from 2 to 3wt%.

The additions of copper and nickel are well known strengthening additions for aluminium alloy bearing materials. Additions below 0.7 wt% do not produce the required strengthening effect whereas additions above 1.3 weight% render the alloy difficult to process. At higher contents of copper and nickel, only relatively small rolling reductions are possible before annealing heat treatments are required which increases the cost of the material.

Vanadium has the effect of increasing the toughness of the alloy. Below 0.1 weight% the effect diminishes rapidly whereas above 0.3 weight% there is an embrittling effect. Preferably, the vanadium content is maintained at a maximum of 0.2 weight%.

Manganese in addition to being a chemical alloy strengthener, is a well known grain refining agent producing smaller grains and hence greater strength than would be the case without it. Below 0.1 weight% the grain refining effect is small whereas above 0.3 weight% manganese, alloy processing becomes difficult and expensive necessitating reduced rolling reductions per pass and additional heat treatments.

We have found that the combination of the two additional elements of vanadium and manganese in small quantities within the limits prescribed above has a synergistic effect wherein the strength of the alloy is raised significantly and, as importantly, the conformability and compatibility of the alloy are not adversely affected to any significant extent. Tests have shown that the alloy shows improved fatigue strength and resistance to scuffing at comparable loads to known strong aluminium alloys whilst retaining ease of manufacture and low processing costs.

However, in the types of engine applications for which this alloy is intended it is the combination of the increased mechanical strength properties together with improved scuff resistance and acceptable seizure resistance which is the surprising effect of the alloy composition of the present invention.

According to a second aspect of the present invention, there is provided a plain bearing comprising a strong backing material and having bonded thereto a layer of a bearing alloy having a composition comprising in weight%: tin 5-10; copper 0.7-1.3; nickel 0.7-1.3; silicon 1.5-3.5; vanadium 0.1-0.3; manganese 0.1-0.3; balance aluminium apart from unavoidable impurities.

The bearing may also include an interlayer of relatively pure aluminium or an aluminium alloy material between the bearing alloy and the strong backing material.

The strong backing material may be steel or bronze for example.

It has been found that the ductility of the alloy containing both vanadium and manganese is significantly greater than alloys containing only one of these additions. It is believed that this feature is responsible for the improved scuff resistance of the material.

Whilst the material of the present invention is primarily intended to be used in relatively highly loaded engines prone to scuffing due to low oil film thickness under arduous operating conditions for example, it will be appreciated by those people skilled in the bearings art that this material would operate perfectly satisfactorily with an overlay coating of the type described hereinabove.

In order that the present invention may be more fully understood, an example will now be described by way of illustration only with reference to the accompanying drawings, of which:

Figure 1 shows a cross section through part of a bearing utilising the alloy of the present invention and showing the constituent layers;

Figure 2 is a histogram showing relative scuff resistance results for an alloy according to the present invention and for three comparative alloys;

Figure 3 shows a similar histogram to that of Figure 2 but showing relative seizure results for the same alloys; and

Figures 4A to 4C which show a part cross section of test apparatus for determining scuff and seizure ratings and graphs indicating the test regimes for fatigue (4B) and scuff/seizure (4C) testing.

Figure 1 shows a cross section through part of the circumferential length of a substantially semi-cylindrical half bearing through a plane normal to the axis of the bearing. The bearing 10 comprises a steel backing layer 12 having a layer 14 of the bearing alloy thereon with a thin interlayer 16 of relatively pure aluminium therebetween. The production process for the bearing will be understood from the example production schedule described below.

Bearings produced from the material described above were formed into half bearings for testing. The bearings had a wall thickness 1.75mm comprising a steel thickness of 1.5mm and a lining thickness of 0.25mm.

Other comparative alloys having a composition as set out in Table 1 below were made into bearings of the same dimensions and tested under the same conditions.

Table 1

Material	Composition						
	Sn	Si	Ni	Cu	V	Mn	Al
Comparative 1	12	4	-	1	-	-	Bal
Comparative 2	20	-	-	1	-	-	Bal
Comparative 3	12	4	-	2	-	-	Bal
Inventive alloy	6	2.5	1	1	0.2	0.25	Bal

Mechanical properties of the above alloys are set out below in Table 2.

Table 2 - Mechanical Properties

Material	Lining Hardness (HV2.5)	UTS (Mpa)	% Elong to Fracture	Toughness *	Al Grain Size (μm)
Comparative 1	47	150	20	20	17
Comparative 2	40	120	23	18	16
Comparative 3	47	150	18	19	17
Inventive Alloy	52	180	21	25	12

* Where toughness = (0.66 x UTS) x Elong^n to Fracture, it is the relationship between strength and ductility. It is a rating and has no units.

It may be seen that the inventive alloy is not only stronger than the comparative alloys but has lost no ductility relative to alloys 1 and 3 which are also aluminium-tin-silicon-copper alloys.

The bearings were tested to determine the fatigue strength thereof, the load at which scuffing occurred and

the ultimate load at which seizure occurred. The tests were carried out in a known Sapphire apparatus as shown in Figure 4A. The apparatus 20 comprises a test shaft 22 having a central eccentric portion 24 supported by the test bearings 26, 28, the outer ends of the shaft are supported in slave bearings 30, 32. The shaft is rotated by a drive motor 36 and load is applied to the test bearings 26, 28 by a connecting rod 40 to which is applied a force by a piston 42 which is actuated by hydraulic means 46, 48. Strain gauges 50 measure the applied load. Figures 4B and 4C show typical regimes for fatigue and scuff/seizure testing. The fatigue load capacity is that load which causes fatigue at 200 hours running. In operation, the apparatus shown at Figure 4A applies a load to the test bearings 26, 28 by means of the eccentric portion 24 and the hydraulically loaded piston 42 thus imposing a sinusoidal dynamic load on the bearings. Via a computer control system (not shown), a programmed progressive load increase becomes the basis of the measurement of surface properties. In this mode of increasing load, the minimum oil film thickness steadily reduces and the test measures, via the temperature increase, the load at which the material is wiped or scuffed as it comes into contact with the geometrical inaccuracies in the shaft and/or the load at which the material welds itself to the shaft. Scuff resistance is a measure of material conformability whilst seizure resistance is a measure of compatibility.

Figure 4B shows an illustrative schematic graph showing that as the load on a bearing increases, the number of cycles which it can withstand prior to fatigue diminishes. Figure 4C illustrates a scuff/seizure testing schedule. An increasing load is applied to a test bearing until scuffing or seizure occurs. Scuffing or seizure is

generally indicated by a rise in temperature at the bearing surface. Scuffing tends to be a momentary temperature rise whereas seizure is a prolonged temperature rise accompanied by a fall in oil pressure.

The test results are shown below in Table 3.

Table 3

Material	Sapphire L-N Fatigue 200 hr Load Capacity	Relative Sapphire scuff resistance	Relative Sapphire seizure resistance
Comparative 1	1.14	0.74	0.95
Comparative 2	1	1	1
Comparative 3	1.14	0.53	1
Inventive Alloy	1.34	0.81	0.81

The relative bearing properties shown in Table 3 are based on 18 tests for the inventive alloy and a minimum of 60 tests for each of the comparative alloys. In the Table Al20Sn1Cu alloy (comparative alloy 2) is given a base-line rating of 1 against which all the other alloys, including the inventive alloy, are rated. Thus, the fatigue strength of the inventive alloy is 34% greater than comparative alloy 2, for example.

As may be seen from Table 3, the fatigue strength of the alloy according to the present invention is significantly higher than the three comparative alloys and although lower in actual seizure resistance it also has improved scuff resistance relative to the other known Al/Sn/Si comparative alloys 1 and 3. The results shown in Table 3 are also depicted graphically in Figures 2 and 3.

In essence the material according to the present invention has a significantly greater fatigue strength than known alloys whilst retaining an entirely adequate resistance to both scuffing and seizure. Thus, the alloys

according to the present invention are particularly useful for those engines requiring a higher fatigue strength and scuff resistance than known silicon containing alloys but which do not require an especially high seizure resistance rating.

CLAIMS

1. A bearing alloy composition comprising in weight%: tin 5-10; copper 0.7-1.3; nickel 0.7-1.3; silicon 1.5-3.5; vanadium 0.1-0.3; manganese 0.1-0.3; balance aluminium apart from unavoidable impurities.
2. A bearing alloy according to claim 1 wherein the tin content lies in the range from 5.5-7 weight%.
3. A bearing alloy according to either claim 1 or claim 2 wherein the silicon content is maintained within the range from 2 to 3wt%.
4. A bearing alloy according to any one preceding claim wherein the vanadium content is a maximum of 0.2 wt%.
5. A bearing alloy substantially as hereinbefore described with reference to the accompanying description and drawings.
6. A plain bearing comprising a strong backing material and having bonded thereto a layer of a bearing alloy having a composition comprising in weight%: tin 5-10; copper 0.7-1.3; nickel 0.7-1.3; silicon 1.5-3.5; vanadium 0.1-0.3; manganese 0.1-0.3; balance aluminium apart from unavoidable impurities.
7. A plain bearing according to claim 6, the bearing further including an interlayer of relatively pure aluminium or an aluminium alloy material between the bearing alloy and the strong backing material.
8. A plain bearing according to either claim 6 or claim 7 wherein the strong backing material is selected from steel and bronze.
9. A plain bearing according to any one of preceding claims 6 to 8 wherein an outer surface of the bearing alloy is provided with and overlay coating layer.

10. A bearing substantially as hereinbefore described with reference to the accompanying description and drawings.

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INVESTOR IN PEOPLE

Application No: GB 0028036.2 14 **Examiner:** Matthew Lawson
Claims searched: 1-10 **Date of search:** 31 May 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): C7A

Int Cl (Ed.7): C22C

Other: Online: PAJ, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2271779 A	(DAIDO) - page 2 lines 11-20, page 2 line 31 - page 3 line 4, page 3 lines 10-13, page 4 line 21 - page 5 line 1 and page 5 line 17 - page 6 line 1.	1-4,6-9
X	GB 2266564 A	(DAIDO) - page 2 lines 6-20 & 25-29, page 3 lines 1-3 and page 4 line 11 - page 5 line 33	1-4,6-9
X	US 5470666	(TANAKA) - column 2 lines 30-35 & 45-49, column 3 line 66 - column 4 line 40, column 4 lines 56-66 and figures 1 & 2.	1-4,6-8

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		